The Study on the Urban Spatial Structure Change By High Resolution Remote Sensing Imagines—the Case of Shijiazhuang City

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ABSTRACT: Urban spatial structure change is one of the most important parts of urban features, it comes from the process of the urbanization and has both inner filling and outward expansion. Under the support of high resolution remote sensing images and geographic information system (GIS), this article analyzes the urban spatial structure changes in the built-up area of Shijiazhuang city from 1994 to 2003. These analyses focus on the aspect of the urban land types and its area, the value of urban land assets and the density of land assets and its change rate, the various types of building area and the building floor area ratio (FAR), the urban population size(PS) and population density(PD) and its change rates. The study discloses the laws of urban spatial structure evolution in order to compile the master urban planning and administrate urban construction.
KEYWORD: RS; GIS; Urban land; Spatial structure; Change model

21 century is the century of the city, city development has become the theme of world development. The developed countries have entered the advanced stage of urbanization. The world's population and accounts for 2/3 of most developing countries is at the preliminary stage of urbanization. So the developing countries urbanization, especially for the city level in about 50% of the China, it is playing an important role in world urban development. The city progress of the China, becomes a hot concern for in new areas of research evolvement of city spatial structure. More analyses on urban land use often focus on the aspect of urban expansion, and few pays attention to urban spatial structure change, urban inner land use, the evolution of functional area, all kinds of building area, the density of land assets, population density and its change rate(He Haibin,2005; Zhu Huiyi,2001). This paper fastly and accurately obtains urban land types, urban land area, the building area and the building floor area ratio (FAR), with help of high resolution remote sensing images and geographic information system (GIS). The combination of Shijiazhuang city urban datum land price and the statistical data, the value of urban land assets and the density of land assets, population density(PD) and its change rate are availed. These data disclose the laws of urban spatial structure evolution, urban spatial structure changes guide the city space reasonably increasing, and provide a method and theory to guide the rational planning of city functional zoning.

1 RESEARCH SCOPE AND METHOD

1.1 *Research scope*

This research selects as the subject of experiment Shijiazhuang city in Hebei province, China, and is intended to study urban spatial structure evolution. The urban domain part is located at the east longitude between 114°23´ and 114°42´, north latitude between 37°58´and 38°58´, the central North China Plain, including 5 administrative units, the urban total population respectively is 141.64 million and 211.09 million people in 1994 and 2003.

1.2 *Research method*

The paper employs the high resolution remote sensing images as the prime data source, combined with statistical data and the urban benchmark land price. Remote sensing (RS), GIS, statistical and investing method are assumed in data collecting and analyzing process. ArcGIS 9.0 version, PCI 9.0 software and man-machine interaction interpretation have been used in disposing the data, collected by the high-resolution remote sensing images. The interpretation results are processed under the condition of GIS. The urban land types and its area, the various types of building area are gained by an exploration of the figure, 2 stages from 1994 to 2003, based on spatial overlays. To obtain the spatial and attribute data of land use change, on this basis, urban

structure and form are carried on the dynamic analysis of land use change.

1.3 *Urban land type systems*

City refers to the non-agricultural industries and non-agricultural population aggregation, is the main features of the residential. The essence of this process is that, the change in the nature of land use is agricultural land into land for city construction and development, the regional differences of basic form and city reflects the city layout of the inner function area.

According to the urban land use goals and the city land use characteristics, the change of urban land use mainly includes the contents of the types, quantity, intensive utilization, structure, form, the integrity of the city land use change, including not only the urban expansion in the city of incremental land quantity and type structure brings, but also the urban inner intensive utilization of the filling and urban renewal.

Based on the reliability of remote sensing imagery data, code for classification of urban land use and planning standards of development land(GB50137–2011), with the present research features, the study will focus on the 8 categories of urban land, including residential(R), administration and public services(A), commercial and business facilities(B), industrial and warehouse(M), street and transportation(S), municipal utilities(C), green space(G), the other(O), total land area(T).

In order to facilitate the characteristic of urban spatial structure and research, according to the overall planning of Shijiazhuang city(1991-2010) and the Shijiazhuang city map of urban benchmark land price in 1998 and 2003, the built-up area of the Shijiazhuang city is divided into 5 regions, respectively, as the central region(CR): the Heping road, Huaian road, Tiyu street and Zhonghua street of the besieged city area; the central region, Jingguang rail way and Zhongshan road surrounded area of Northeast region(NE), Southeast region(SE), Northwest(NW) and Southwest region(SW).

2 DATA PROCESSING

2.1 *Data source selection*

Along with the spatial resolution increases, more detailed geographic features will be clearly displayed, this provides the basis for the use of high spatial resolution remote sensing monitoring of surface environment change and human activities. This study uses aerial photographs (June,1994, black and white photograph, 1m spatial resolution), and the digital orthography map (DOM, 1:10000) as the main data source, and IKONOS satellite imagery (November, 2003 imagery data, spatial resolution 1 meters panchromatic and multi spectrum resolution 4 meters) as the basic information source, and PCI software, which works in disposing the remote sensing imageries, then interpret the information of urban land and analyze it with the help of ArcGIS. The research also refers to the general urban planning of Shijiazhuang city (1991-2010), China City Statistical Yearbook, 2003 city administrative divisions and the urban benchmark land price material.

2.2 *Remote sensing imagery processing*

2.2.1 *Image geometric rectification*

Satellite data correction. The ground resolution IKONOS panchromatic band is 1 meters, the correction method can not guarantee the accuracy of correction using polynomial. Need to use is to correct the image data of IKONOS orthographic rectification method. The raster image pixel gray value rectified after resampling, in the work of image pixel brightness value of resampling by using two linear interpolation or three cubic convolution interpolation. Because the aerial used for orthophoto map, image has been geometric correction method, projection conversion using geographic coordinates associated to the orthophoto map to check the aerial pixel after correction of IKONOS images and the projection of the matching condition; in order to ensure the city land types on the spatial overlay image classification is generated after analysis in order to reach the precision requirement, the selection of IKONOS image after correction for baseline correction of aerial photographs again, makes the precise matching of two images in pixel. In the correction process, selection of image brightness resampling uses bilinear interpolation method.

2.2.2 *Imagery highlighting and image merging*

Before the image merging, the IKONOS pan & multi-spectrum images should be highlighted. The readjusting process mainly to emphasize the detailed texture and lower the noise to the minimum, with help of linear extension and high pass filter, so as to achieve ideal effect. To the black and white aerial photos, PCI software was applied to the images by directional filter and HIS transform image fusion.

3 URBAN SPATIAL STRUCTURE INFORMATION ABSTRACTION

3.1 *Urban land types interpretation mark*

City is a complex of the collection by various construction and traffic facilities, is a large-scale complex structure, and comprehensive function and various factors of the artificial ecological system.

These complicated space structure buildings have been recorded in IKONOS and aerial images (DOM), the corresponding relationship between using ground spectral reflectance characteristics and image gray scale, color and texture structure, size, morphology, combined with the object image texture, structure, location and combination form characteristics, using the comprehensive analysis method to identify different objects, and interpret urban land types. The structure complexity of city landscape, poses great difficulty to interpretation, so, the original land classification data were referred in fixing the types of unknown land. The priority should go to fix remote sensing marks according to the remote sensing image features and the relation between land and objects.

3.2 *Urban land types, land assets information collection*

3.2.1 *Urban land types interpretation in1994*

Urban land type inference interpretation of spectral feature and morphological characteristics is the use of remote sensing images and photographs of land types and the land boundary. Spectral characteristics of main are the image color, hue, intensity and texture. Morphology is mainly form, size, order and combination and location. Grouped according to these characteristics, will have the same characteristics of classified as a class, to distinguish the different land use types. Interpretation process is a comprehensive application of professional knowledge, the interpretation process, determine the interpretation and the land use characteristics of relationship is very important. Firstly, according to the building shape infer its land use characteristics, and then according to the characteristics of building group combination, unit courtyard boundary and courtyard characteristics, geographic location characteristics, road, building density and green features determine the land use nature.

The urban land types and the area of various land types are gained, based on the establishment of the urban land type of interpretation of signs, by the man-machine interactive interpretation of aerial images in 1994 under the support of ArcGIS. The data refers to Tab. 1.

3.2.2 *Urban land types interpretation in 2003*

Based on interpretation marks of urban land types and IKONOS images characteristics, the urban land types and the area of various land types are collected in Shijiazhuang city in 2003. The urban land database in Shijiazhuang city is constructed. The results refer to table 1.

3.2.3 *Urban value of land assets, land assets density*

By using ArcGIS software, urban land database in 1994 was overlaid the map of urban benchmark land price in 1998. The benchmark land price contains the data of commercial, residential, industrial benchmark price. We get the data of urban land types and its land price, B price corresponding to A, B and C; R price corresponding to R; M price corresponding to M. All kinds of land area are multiplied by their price, the various types of land assets value of each region can get. Also, the urban land assets density is the data that land assets value is divided by the total area of every kind of land. The land of S, G, O is not been calculated. Similarly, the city land database in 2003 superposition urban benchmark land price, the land assets value and the distribution of land assets density of each region are acquired. The results refer to Tab. 2.

3.3 *Urban buildings, population information extraction*

3.3.1 *The various urban buildings interpretation*

In this study, kinds of buildings are divided into residential building (RB) , public construction (AB), the business buildings (BB), industrial buildings (MB), public facilities construction (CB), total construction (TB) according to the nature of urban land division. The building floor area ratio, building density and building height reflect the city land use intensity information. Given the floor is smooth, and the angle between the sun, the satellite height and the azimuth is fixed, a rigorous geometrical relation would be set between the floor building and the shadow of the building concerned. Based on the full height of the building concerned, the given time, and the unit floor height of different building types, its floors could be calculated. The figure of total building area against unit building floor, is floor area ratio. For aerial photos, the height of the building concerned is located by using the solid images' aerial photos of adjacent orbit. Parallax bar is used to get the parallax of the building concerned, then to get the height of the building and its unit floor height, in succession, the total construction area and the floor area ratio. The results see table 3.

3.3.2 *Urban population and population density calculation*

The main family scale is 3.5 persons households in Shijiazhuang City in 1990, 3 persons households in 2000, city housing vacancy rate is about 10% (He Wenyan, 2009; Jia Shijing, et al., 2010). According to the residential construction area and per capita housing area of each region, urban population size(PS) of each spatial region is calculated. There is population density that urban population size is divided by the total land area of each region, the results see table 2.

Tab. 1 The urban land type, area of urban land and its change rates Unit: ha, ha/year

location		R	A	B	M	S	C	G	O
1994	Region	4657.74	1720.56	182.03	2762.84	2134.8	351.05	888.60	132.31
	CR	834.21	275.63	126.32	115.85	296.63	19.25	53.61	0.00
	NE	657.22	187.18	2.24	1197.44	356.12	111.33	105.00	20.00
	SE	772.02	312.40	14.43	487.97	390.70	71.77	184.65	37.00
	NW	459.06	329.44	37.23	362.56	389.96	16.57	130.78	5.31
	SW	1975.23	615.91	18.10	599.02	701.39	132.12	394.56	30.00
2003	Region	5046.09	1785.04	323.58	2838.18	2203.99	368.01	1127.05	730.60
	CR	834.57	234.12	164.81	116.29	298.81	19.25	53.64	0.00
	NE	672.88	226.78	2.24	1228.73	359.21	111.33	184.94	240.90
	SE	864.55	340.11	29.84	494.41	432.23	76.89	322.84	212.83
	NW	548.68	344.38	73.00	398.21	395.48	26.07	155.06	111.59
	SW	2125.41	639.65	53.70	600.54	718.26	134.47	410.58	165.28
Ki	Region	43.15	7.16	15.73	8.37	7.69	1.88	26.49	66.48
	CR	0.04	-4.61	4.28	0.05	0.24	0.00	0.00	0.00
	NE	1.74	4.40	0.00	3.48	0.34	0.00	8.88	24.54
	SE	10.28	3.08	1.71	0.72	4.61	0.57	15.35	19.54
	NW	9.96	1.66	3.97	3.96	0.61	1.06	2.70	11.81
	SW	16.69	2.64	3.96	0.17	1.87	0.26	1.78	15.03

Tab. 2 The urban land assets value, land assets density and its change unit: billion yuan, billion yuan /year,yuan/sq m/year

location		R	A	B	M	C	K_R	K_A	K_B	K_M	K_C
1994	Region	554.62	305.21	57.06	186.97	49.11	36.17	14.00	4.96	5.19	3.52
	CR	192.27	96.45	47.11	9.28	5.66	8.35	-0.16	2.16	0.11	0.11
	NE	67.74	27.29	0.52	108.78	12.50	3.85	2.47	0.02	0.36	1.17
	SE	101.86	56.57	2.04	28.01	9.85	7.37	2.43	0.53	1.23	0.80
	NW	102.45	71.41	6.99	16.47	4.02	7.91	4.15	1.00	1.27	0.50
	SW	100.29	53.48	0.40	24.43	17.08	6.46	1.78	1.25	2.22	0.94
2003	Region	880.11	431.18	101.74	233.70	80.81	61	71	1	16	89
	CR	267.42	95.00	66.59	10.23	6.64	100	62	35	9	57
	NE	102.44	49.49	0.67	112.05	22.99	55	80	74	0	105
	SE	168.17	78.44	6.84	39.12	17.09	70	55	97	24	95
	NW	173.67	108.76	16.01	27.92	8.55	104	110	35	27	95
	SW	158.41	69.50	11.63	44.38	25.54	26	24	216	37	67

4 RESEARCH ON THE URBAN SPATIAL STRUCTURE CHANGE

This study relates to the changes of urban spatial structure of main aspects: urban land types and its area change, the value of land assets and the density of land assets change, various building area and FAR change, urban population size and population density change. The change rates of the main indexes are expressed in a formula: Ki=(LA(i,t2)-LA(i,t1))/(t2-t1) Where, Ki as an average annual rate of change of city spatial structure i index in the study area, LA (i, t1) and LA (i, t2) respectively for the city spatial structure index i in the t1 stage and t2 stage.

4.1 *Urban land types and urban land area*

Coverage change firstly is reflected on urban land use total coverage. An analysis of the total coverage change of different urban land types tells its general trend and corresponding structure development. A study on the coverage of 1994 and 2003 different urban land types change scope during the 9 years (Tab. 1).

Tab. 1 shows that residential land area expansion ranks first, in the past 9 years, with an increased area of 388.35 ha; of which the main growth in the southwest, southeast and northwest; with second green land and commercial land area, increased respectively 238.45 and 141.55 ha, mainly in the southeast to increase green area, commercial land area for a major increase in the central region; public facilities land area increased minimum area of 16.96 ha. The national standards of Code for classification of urban land use and planning standards of development land (GB50137–2011), urban land use structure of R, A, M, S and G five major categories of land for construction use, land ratio shall comply with 25~40, 5~8, 15~30, 10~25 and 10~15%. Through the interpretation of remote sensing

Shijiazhuang 2 stages built-up area, 5 rates of urban land types are respectively 35~36, 12~13, 20~22, 15~17, 7~8%. Except green space, its ratio of 8% is lower than the standard. Future planning should adjust the proportion of green land. City spatial form evolution is an important feature of the city of Shijiazhuang City, the study period, the process performances for internal filling and promote regional expansion form two kinds of expansion.

4.2 *Urban land assets, land assets density and its variation*

The benchmark land price of Shijiazhuang city land type overlaid the urban land database of each period, the urban land assets value and the land assets density of the different region are got, various land types value of 2 stages and their distribution see table 2.

Tab. 3 The building area, population size, population density Unit: ha(/year), million people(/year), people/sq km(/year)

location		RB	AB	BB	MB	CB	PS	PD
1994	Region	3920.18	1063.19	217.62	756.69	74.66	141.64	11040
	CR	805.95	282.42	188.57	49.89	6.53	29.12	16915
	NE	529.30	100.72	3.28	337.76	22.78	19.12	7253
	SE	787.15	177.09	5.89	131.24	15.82	28.44	12524
	NW	291.62	165.45	2.94	75.64	2.44	10.54	6199
	SW	1506.16	337.51	16.94	162.17	27.10	54.42	12144
2003	Region	6353.89	1092.91	392.40	792.14	77.89	211.09	14682
	CR	1237.06	283.51	311.83	50.01	7.41	41.10	23873
	NE	818.06	118.50	3.28	351.04	22.85	27.18	8978
	SE	1279.58	181.39	12.62	137.83	17.90	42.51	15551
	NW	557.63	186.33	12.22	84.81	3.42	18.53	9218
	SW	2461.55	338.17	52.44	168.45	28.32	81.78	16738
Ki	Region	270.41	3.30	19.42	3.94	0.36	7.72	405
	CR	47.90	0.12	13.70	0.01	0.10	1.33	773
	NE	32.09	1.98	0.00	1.48	0.01	0.89	192
	SE	54.71	0.48	0.75	0.73	0.23	1.56	336
	NW	29.56	2.32	1.03	1.02	0.11	0.89	335
	SW	106.15	0.07	3.94	0.70	0.14	3.04	511

Tab. 2 shows, the value of the city land assets is 1152.96 billion yuan in 1994, and 1727.54 billion yuan in 2003, with an average annual growth rate of 4.6%. The average annual growth of the residential is the fastest, an average annual increase of 36.17 billion yuan, increasing fastest for this region of the CR, SE and NW, with an average annual growth rate of respectively 8.35, 7.37, 7.91 billion yuan. The value of land assets of A, is the secondly fastest, an average annual increase of 14 billion yuan, of which the NW's fastest growing, with an average annual growth rate of 4.15 billion yuan. The value of the rest land assets of the different region growth is closer.

The density of city land assets except M, in the 5 region, the CR, of various land types is the biggest. Industrial land assets density in NE is biggest, and about 910 yuan per square meters, the NE is industrial district, mainly consistent with functions of planning distribution; C, the density of city land assets with an average annual growth rate of the fastest, for 105 yuan per square meters. In the SE, land for B, C, an average annual growth rate of land asset density is the fastest, respectively 97 and 95 yuan per square meters. In the NW, for R, A, an average annual growth rate of the land asset density is the fastest, respectively 104 and 110 yuan per square meters. The SW, with an average annual growth rate of commercial and business land asset density is the fastest, 216 yuan per square meters.

4.3 *Urban building area and the FAR*

There are 5 categories buildings, respectively RB, AB, BB, MB, CB, TB. Various building area see Tab. 3.

Tab. 3 shows: the FAR of built-up area changed little, during the study period increased by 0.07, total construction area of 1401.09 ha increases. In the 5 region, for the CR, the FAR of various building are maximum, such as the FAR of BB is 1.89, for all types of building, the FAR of RB increases fast, the rate of increase is 0.4-0.5, which indicates that urban land use becomes more intensively.

The area of RB increase of all kinds of building area is the fastest, followed by BB, third is MB. In 5 regions, the area of RB of SW, SE, CR increased most quickly, with an average annual growth rate of respectively 106.15, 54.71, 47.90 ha. The area of BB of the CR, SW increased most quickly, with an average annual growth rate of respectively 13.7, 3.94 ha. The area of MB of the NE increased most quickly, with an average annual growth rate of as 1.48 ha. The area of AB of NW, NE increased quickly, with

an average annual growth rate of respectively 2.32, 1.98 ha.

4.4 *Urban population size, population density*

Urban population size(PS) of different spatial region is gained in 2 stages, that city RB area is divided by per capita housing area. Population density of each region is calculated by that each region population size divided by each region total area, see table 3.

Tab. 3 shows, the total population and PD were significantly increased, the average annual growth of 7.72 million, average annual growth of population density of 405 people per sq km. In 5 areas, population increase most quickly for SW, SE and CR, the population average annual growth were 3.04, 1.56, 1.33 million people. The population density increased quickly as CR and SW, the average annual growth of 773, 511 people per sq km respectively; population density increased most slowly for the NE, the average annual growth of 192 people per sq km. During the study period, the number of population and acreage of built-up area are on the increase, the number of population grew faster than the built-up area, therefore, population density is increased. In 2003, the CR, SW and SE, population density is the biggest, the more crowded. The amount of population and housing area are also on the increase, from 1994 to 2003, the per capita housing area increased from 22 to 27 square meters, the per capita housing area increased by 5 square meters, housing conditions improved.

5 CONCLUSION

1) Urban land types, urban land area, area of all kinds of buildings were interpreted by using high resolution remote sensing images, combined with the housing area, urban benchmark land price and statistical data, this aims to provide an effective means for the research of city land value of the assets under rapid development and the population density, the number and density change, provide the basis for the urban spatial structure change, city planning and government decision-making.

2) During the study period, urban construction land change tends to be more reasonable in Shijiazhuang city. To 2003, Shijiazhuang city land use structure is in accordance with the provision of state planning and construction of built-up area, residential land, administration and public services land, industrial storage land, street and transportation and green land five major categories of land for construction use, five kinds of main land structure ratio for urban built-up area respectively are 35, 12, 20, 15 and 8%, only the green area is 2 percentage points lower than the standard, in the future in the renew of the old city and the new development of land should increase the green land. In addition to the land area of administration and public services decrease in the central region, Shijiazhuang city value of the land assets and urban land assets density increased, the value of residential land average annual growth is not only the fastest, but also urban land value largest increase. The FAR increases with the expansion of the built-up area, an increase of 0.03, a total construction area of 1401.09 ha. Total population and population density of 5 regions were significantly increased, urban land more save and more intensive. In addition to residential land, the average annual growth rate of city green land is the largest, 26.49 ha of land. Urban land use and urban spatial structure are more reasonable.

3) Analysis of the whole and the 5 regions of urban spatial structure, functional area are clear. The central region is the business district, commercial land area in 5 regions ranks the largest, highest value of land assets, the highest population density. The northeast region is industrial and warehouse concentrated area, the area of industrial land is the largest, highest value of industrial land assets and industrial land assets density, the lowest increase of population density.

In addition to other land, the area of green space and residential land increased rapidly, in the southeast region, the average annual growth rates were 15.35, 10.28 ha. In the southwest region, residential land area of rapid growth, the average annual growth rate of 16.69 ha. In the northwest region, area of residential land and commercial land increased rapidly, the average annual growth rates were 9.96, 3.97 ha. To increase the residential construction area of the fastest is the southwest and southeast region, the average annual growth rates were 106.15, 54.71 ha; secondly, as the central region, the average annual growth rate respectively is 47.90 ha. The value of city residential land assets is the largest in the central region, followed by the northwest, southeast, southwest region, therefore, the central, northwest, southeast, southwest region as a city district mainly residential area, population density and population increased most quickly.

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